ELECTRON DENSITY AND TEMPERATURE DIAGNOSTIC OF LASER CREATED TITANIUM PLASMA

S. Nait Amor, T. Kerdja, S. Abdelli, S. Lafane,
S. Messaoud-Aberkane, K.Yahiaoui, and S. Malek
Centre de Developpement des Technologies Avancées.
Lot. 20 Aout 1956, BP17. Baba Hacen, Alger. Algeria
E-mail: naitamorsamir@hotmail.com

In this contribution we present time and space evolution of plasma parameters during ablation of titanium target in vacuum and at low nitrogen pressure using KrF laser. Electron density is measured from Stark Broadening of singly ionised species; electron temperature is determined from Boltzmann plot of lines intensities of the same species.

1 Introduction

In recent years, pulsed laser deposition has become an attractive technique for depositing a wide variety of materials. Optimisation and control of such process require the understanding of vaporisation and plasma build-up mechanism, plasma playing a key role since it determine the formation of reactive species and high-energy ions [1].

Among the several diagnostics technique generally used to probe plasma plume, optical emission spectroscopy appear to be popular choice owing to its non-intrusive. Electron density and temperature can also be determined from spectral lines analysis. In this contribution, we present the spatial and temporal evolution of electron density and electron temperature at early stage of ablation. For electron density measurement, we have adopted a technique based on the line width analysis of selected emission lines. The electron plasma temperature is determined using the Boltzmann plot method.

2 Experimental arrangements

Material vapour is produced by focusing a KrF laser beam (248 nm, 30 ns) on a pure titanium target surface at fixed laser fluence of 16J/cm² and at 1 mbar ambient nitrogen pressure. The plasma plume is imaged onto the entrance slit of 0.8m spectrometer (Spex 1704) equipped with 1200 grooves mm^{-1} grating, blazed at 0.3 μm. The entrance and exit slits of spectrometer are adjusted to 80μm, giving spectral resolution of 0.64A° and spatial resolution of 80μm. Signals are recorded by means of a fast phototube (Hamamatsu R928) and digital oscilloscope (Tektronix TDS3032).

3 Results and discussions

3.1 Electron density

Titanium plasma emission is collected from region along the axis of the plume, and shows Ti^{++}, Ti^{+} and Ti emission. Assuming that the Stark effect is the mean broadening process taking place in the plasma, the electron density can be determined by measuring the line width through the relation $\Delta\lambda_{1/2} = 2w(n_e/10^{16})$ Å, where w, $\Delta\lambda_{1/2}$ and n_e are the electron impact parameter, line width (FWHM) and the electron density respectively [2]. In our case, the electron density is determined from line width of Ti^{+} line at 3483A°. At each given distance of observation, the temporal evolution of electron density shows a fast increase with delay time up to the maximum value and decreases with increasing delay time (fig.1). The increase of electron density in titanium plasma at earlier times can be attributed to the low density of electrons reaching the observation zone with Ti^{2+}. The plasma front is mainly constituted from Ti^{2+} and Ti^{+} ions. Assuming LTE equilibrium, the Ti^{2+} density is lower than the Ti^{+} density, so the electron density in the plasma front can be assumed less than the electron density in the plasma core. The fast droop of electron density after maximum value is due to the recombination process and the plasma expansion.

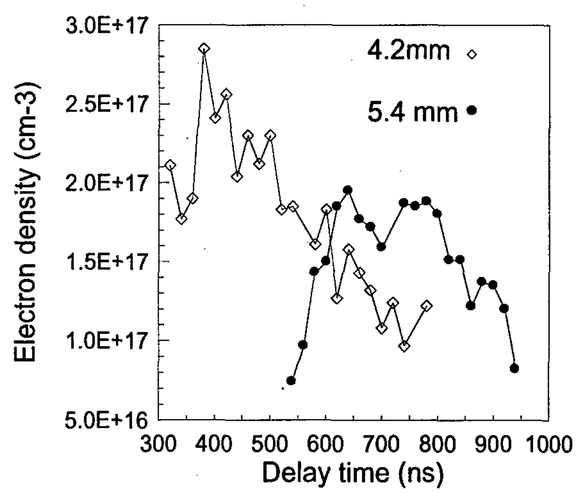

Figure (1): Temporal evolution of electron density at two distances from the target surface.

On fig.2 the temporal evolution of the maximum electron density is well fitted by t^{-1} scaling law up to 350ns and t^{-3}

scaling law beyond. Assuming one-dimensional expansion at low distances and three dimensional for higher distances, our experimental results are in good agreement with theoretical plasma dynamics models [1].

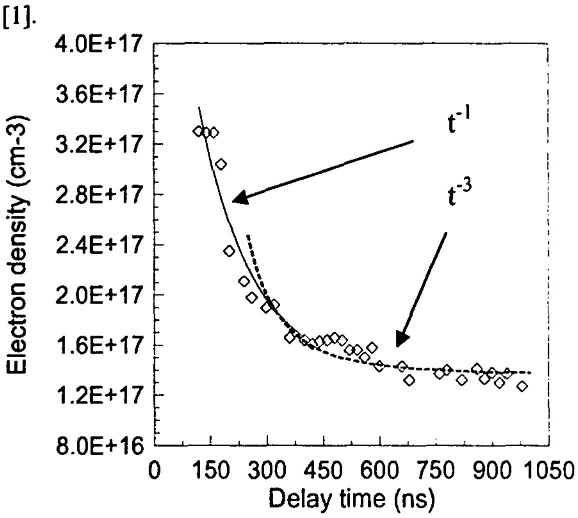

Figure (2): Temporal evolution of maximum electron density at different distances from the target surface.

3.2 Electron temperature

Plasma electron temperature is determined from Boltzmann plot method of 399.8nm, 334.1nm and 319.9nm Ti lines. Fig.3 represents the temporal evolution of the electron temperature at 2.4mm and 6mm from the target surface. At both distances, temporal evolution of plasma electron temperature shows a temperature increase with time at earlier stage of plume expansion and decreasing shape at longer time, the decreasing became slower at longer delay. The collision of the gas molecules with the plasma front leads to the dissociation and ionisation of the gas molecules, so the plasma thermal energy shows a decrease.

Decreasing of electron temperature is due to the adiabatic expansion of plasma plume. During this expansion thermal energy is converted into kinetic energy and plasma cools down rapidly [3]. At later time electron temperature begins to decrease more slowly due to the energy released by the recombination, which compensates the cooling due to expansion process. Temporal evolution of plasma electron temperature is well fitted by t^{-1} in good agreement with adiabatic model of plasma expansion where γ is equal to 1.33, fig.(3,4).

4 Conclusions

In this contribution, we report the spatio-temporal evolution of plasma parameters using lines emission of titanium plasma species. Both electron density and electron temperature show fast increasing shape at earlier times up to the maximum values and then decrease rapidly with increasing delay times. Increasing of electron density is due to the low electron density in the plasma front reaching the observation zone with Ti^{++} species. For electron temperature, collisions of plasma front species with gas molecules lead to cooling down of plasma front and increasing gas molecule temperature. The droop of both electron density and electron temperature after reaching maximum values is due to the plasma expansion.

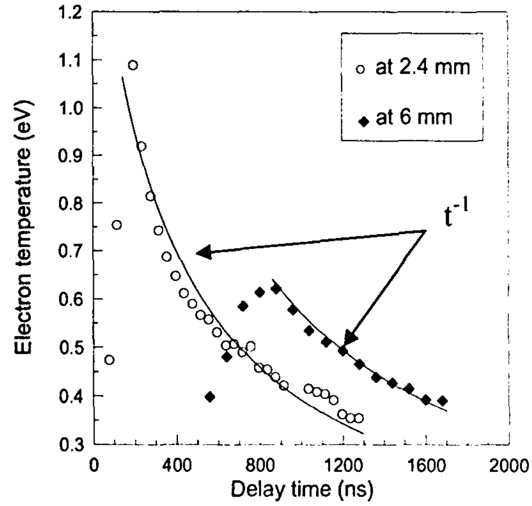

Figure (3): Temporal evolution of electron temperature at two distances from the target surface.

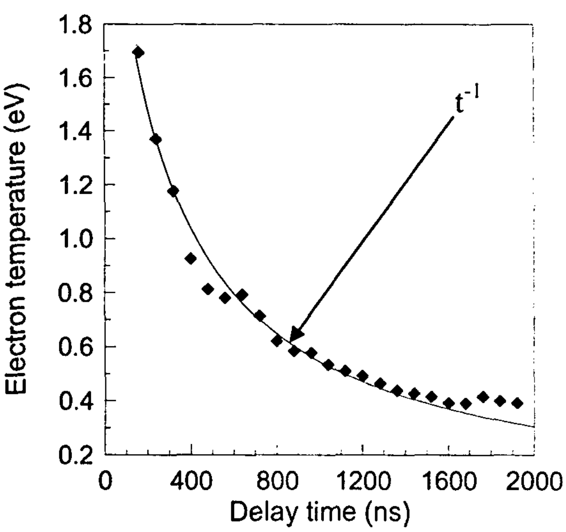

Figure (4): Temporal evolution of maximum electron temperature at different distances from the target surface.

4 References

[1] F. Fuso, L.N. Vyacheslavov and G. Masciarelli, J. Appl. Phys., **76**, (1994), 12.

[2]J. Hermann, Al. Thomann, C. Boulmer-Leborgne, B. Dubreuil, M.L. Degiorgio, A. Luches, and I.N. Mihaiescu, J. Appl. Phys., **77**, (1995), 2829.

[3] S.S. Harilal, C.V. Bindhu, C. Issac, V.P.N. Nampoori, and C.P.G.Vallabhan, J. Appl. Phys., **82**, (1997), 5.